(12) UK Patent Application (19) GB (11) 2 068 124 A

(21) Application No 8002712
(22) Date of filing 26 Jan 1980
(43) Application published
5 Aug 1981
(51) INT CL[3]
G01R 19/12
(52) Domestic classification
G1N 1A3A 1A3B 1D7
1D7A 3S1B 7E2 7N AHK
(56) Documents cited
None
(58) Field of search
G1N

(71) Applicant
Kenneth Walter James
Fisher, 19 Watchhouse
Road, Pill,
Bristol BS20 0EP
(72) Inventor
Kenneth Walter James
Fisher

(54) Conditioning unit for use with linear variable differential transformers

(57) The invention comprises an excitation and conditioning system for one or two linear variable differential transformers (L.V.D.Ts.) of standard design to give a D.C. analogue voltage output representing:—

(a) Position of motion relative to any datum point.

(b) Velocity of motion.

Automatic internal surveillance of the integrity of the output signals ensures that any electrical failure of the L.V.D.T. or the conditioning unit is immediately indicated.

When using two L.V.D.Ts. driven from separate motions, a further output gives the difference in position of the two motions and can be used to synchronise the motions when required.

An oscillator produces two sinusoidal outputs in quadrature to excite the L.V.D.Ts. and demodulates their outputs signals by means of sample and hold circuitry. By sampling the position signal twice in each cycle excitation ripple is eliminated. By sampling a third time in the next cycle a rate of change of position signal is obtained, i.e., velocity.

GB 2 068 124 A

FA

2068124

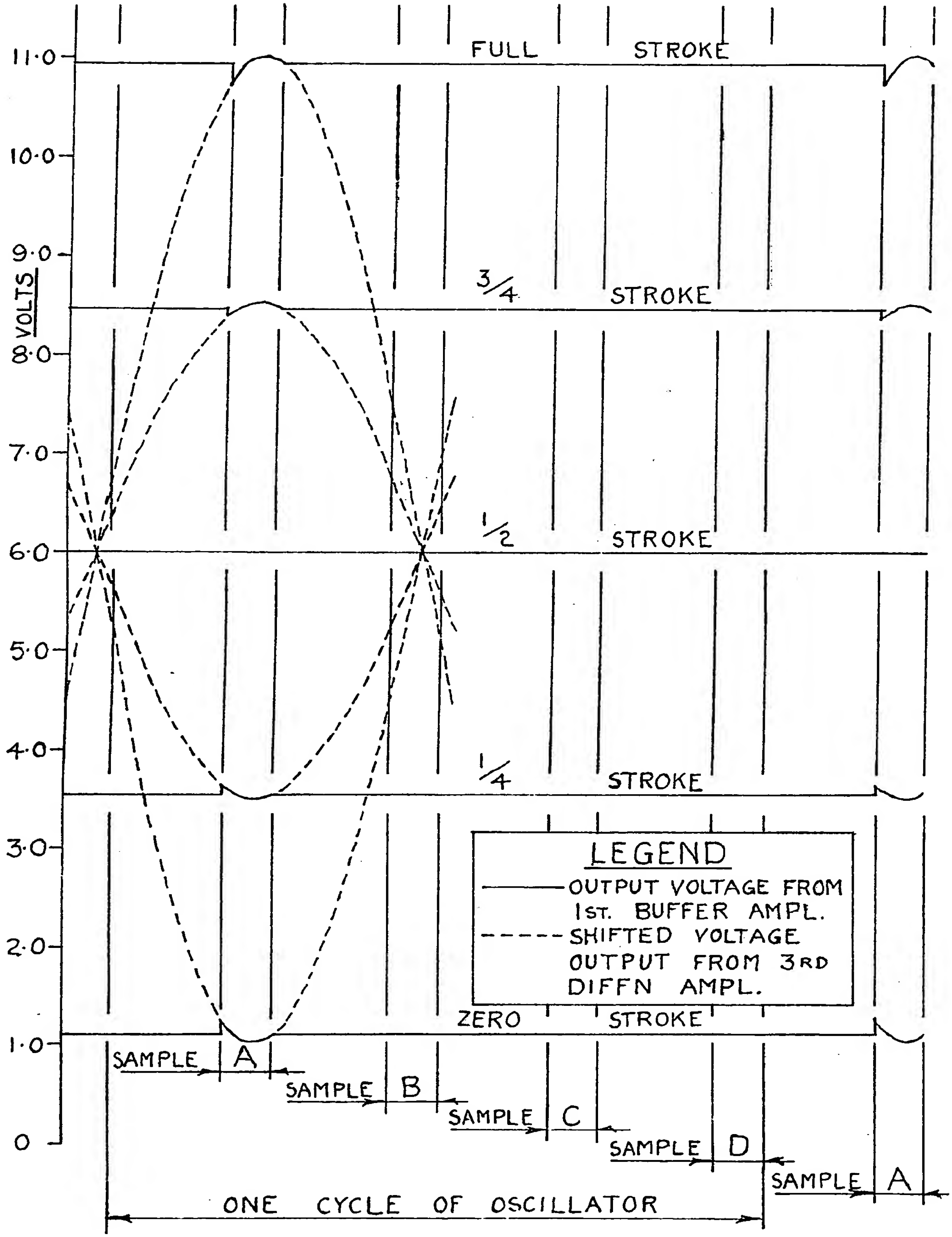


FIG. 1.

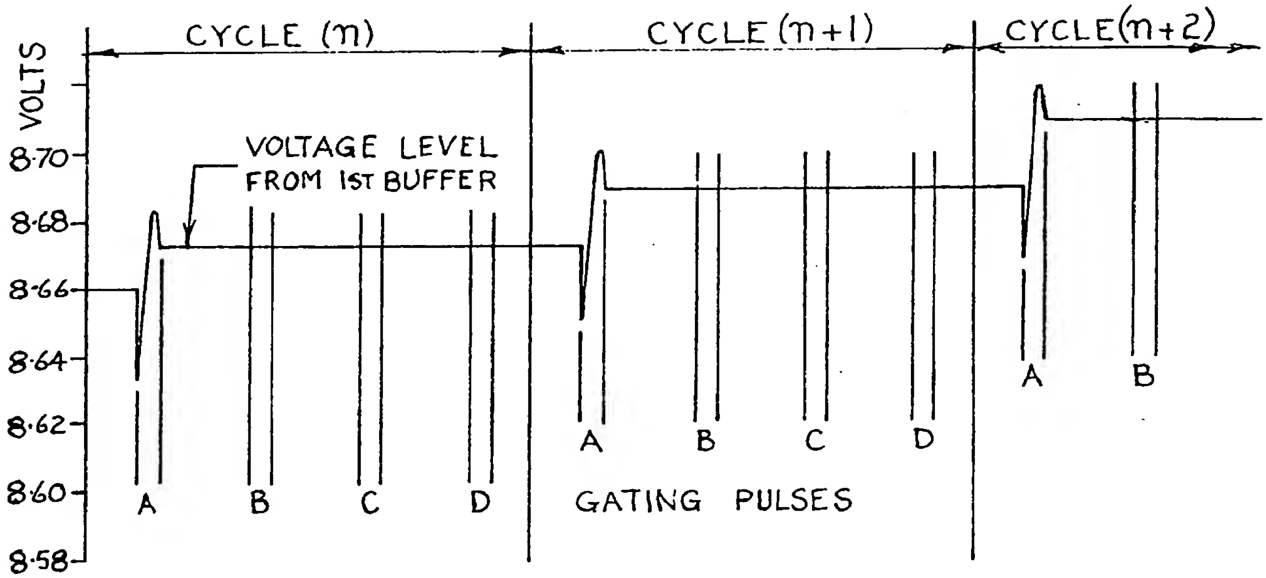
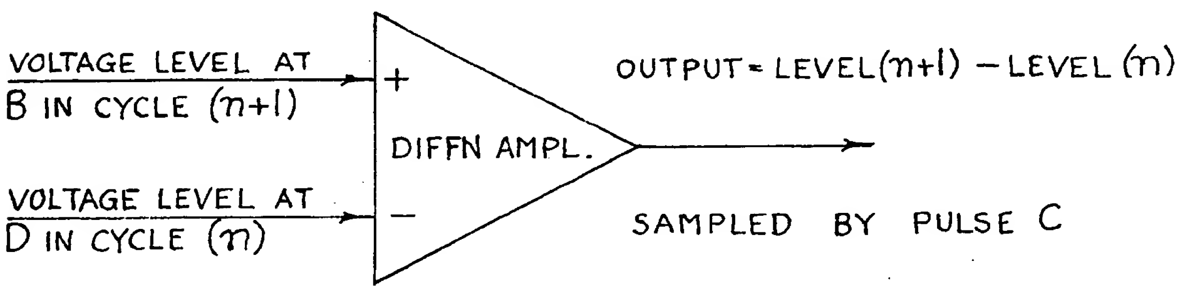
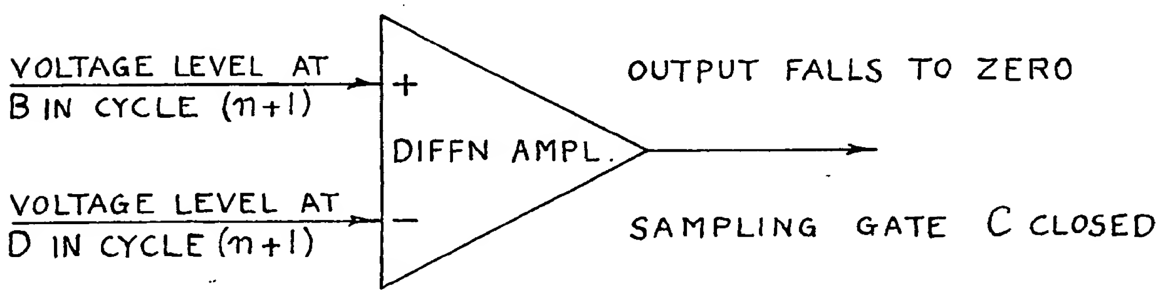


FIG 2a



CONDITION AT THE ARRIVAL OF
GATING PULSE C IN CYCLE (n+1)

FIG 2b



CONDITION AT THE END OF
GATING PULSE D IN CYCLE (n+1)

FIG 2c

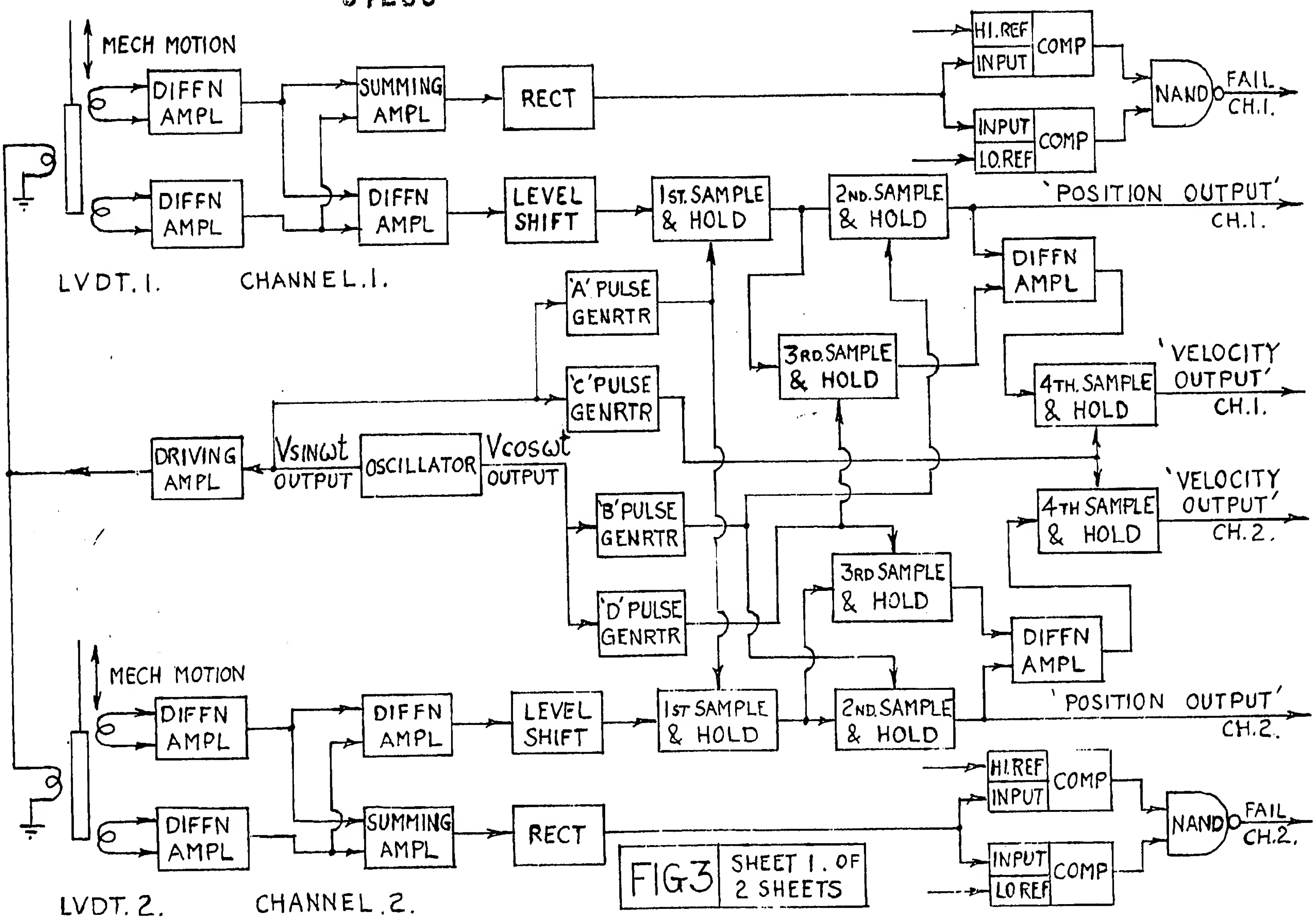


FIG 3 SHEET 1. OF 2 SHEETS

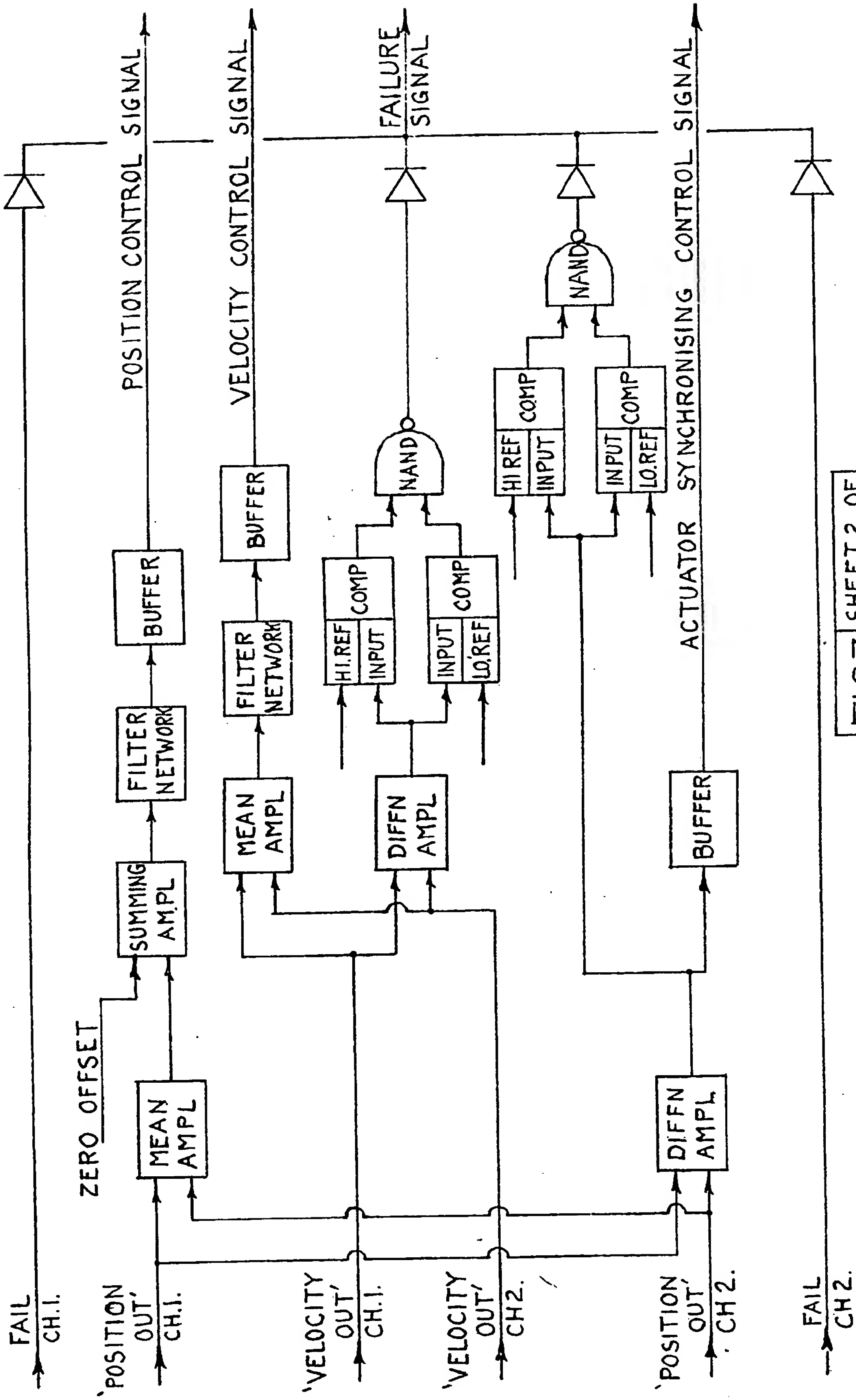


FIG3

SHEET 2 OF 2 SHEETS

SPECIFICATION

Conditioning unit for use with linear variable differential transformers

This invention relates to the excitation and the conditioning of the signals from one or more linear variable differential transformers (L.V.D.T.'s) of standard design so as to give outputs which provide a distance measuring system, a velocity measuring system, and automatic surveillance of the integrity of the output signals. Existing conditioning equipment only provides a distance measuring system which is not self-monitoring. Satisfactory velocity measurement had not so far been obtainable from an L.V.D.T. and a different type of transducer with its own conditioning system is required therefore, which considerably increases the cost and complexity of the system.

The invention is applicable to any mechanical device, which is moved by means of a hydraulic or pneumatic actuator, where feedback signals of position and/or velocity are required for control purposes. Typical applications would be for hydraulic presses, machine tools, variable stroke pumps, injection moulders, remote handling equipment, aircraft or ship steering and stabilising systems and similar servo system devices. The invention is particularly useful where two actuators produce the mechanical motion and the movements of the actuators need to be synchronised. The necessary signal to control the synchronisation is an integral feature of the invention.

The surveillance system produces a failure signal should the output signals cease to be a true indication of the position or velocity of the mechanical device being controlled. This signal can be used to stop the movement of the mechanical device, or cause it to revert to a fail safe position, until the fault producing the false output is rectified.

The invention comprises an electronic circuit composed of readily available standard components mounted on a single printed circuit board approximately 200mm x 150mm in size. The circuit embodies a type of oscillator which gives two amplitude controlled sinusoidal outputs in quadrature at a fixed frequency in the range of 400Hz to 5000Hz dependant on individual applications. This oscillator is used to excite the L.V.D.T. The oscillator also drives two parallel sets of four gating pulse generators which provide four gating signals at intervals of 90 electrical degrees during each cycle. These gating pulses are used to drive sample and hold circuits and are denoted by A, B, C & D in the order in which they occur chronologically.

The two signal coils of the L.V.D.T. feed into separate differential amplifiers. Two parallel sets of amplifiers are used denoted by Channel 1 and Channel 2. Where a single L.V.D.T. is used the signal coils are linked to both channels. When two L.V.D.T.'s are employed, each feeds a single channel. Channel 1 and Channel 2 are identical duplicated circuits; thus only Channel 1 needs description.

The single ended outputs of the signal coil amplifiers are first fed to a summing amplifier which also acts as a rectifier. The output of this amplifier is therefore a D.C. voltage the level of which remains constant within approximately 0.5 volts throughout the total travel of the L.V.D.T. This voltage is fed to two comparators with reference voltages set to give a band gap which contains the normal variation to be expected. The output from each comparator is normally 'HIGH'. Thus failure of either L.V.D.T. signal coil or the oscillator exciting the L.V.D.T. will cause one of the comparators to change state. The resulting 'LOW' will produce the failure signal. This is the first part of the surveillance system.

The same single ended outputs of the signal coil amplifiers are also fed to a differential amplifier. The output from this amplifier will be in accordance with standard practice:– A sinusoidal signal at oscillator frequency, with a maximum amplitude when the L.V.D.T. is at the beginning of its stroke which decreases to zero as the L.V.D.T. moves to midstroke, and then increases again with a phase inversion of 180° during the motion from midstroke to end of stroke. Typical output signals are shown dotted in Fig. 1 for zero; $\frac{1}{4}$; $\frac{1}{2}$; $\frac{3}{4}$ and full stroke. This signal needs to be demodulated and filtered to remove ripple at oscillator frequency before a useful 'Position Output' can be obtained. One part of this invention provides an improved demodulation system which can be used to give a 'Position Output' devoid of oscillator ripple with a resolution better than one part in ten thousand, ie. .01mm with a stroke of 100mm. This is ten times better than that obtainable with existing systems unless very slow movement is used. In this invention the absence of filters to remove ripple at fundamental frequency much improves the frequency response of the system. The maximum linear velocity for a given resolution will depend on the oscillator frequency employed. Obtainable values from this equipment for an L.V.D.T. with a stroke of 100mm are 50mm/sec for a resolution of 0.1mm or 500mm/sec for a resolution of 0.1mm. Some filtration may be employed on the final output signal to remove random noise produced by the electronic components but this will not impair the useful frequency response of this system.

To continue the description of Channel 1. The output signal from the differential amplifier requiring demodulation is first moved by a voltage shift network so that it is always a positive voltage. For example $+6V \pm 5V_{max}$ would be suitable but other voltage ranges could be used. The phase is also adjusted where necessary to coincide with that of the oscillator. Gating Pulse 'A' is used to open and close a suitable electronic switch such as one of the cos/mos type. When closed the switch connects a low leakage capacitor to the signal for a short period of each cycle as the signal approaches its first peak. The voltage across the capacitor at the instant that the switch opens remains virtually constant until Pulse 'A' closes the switch again during the next succeeding cycle and any variation in signal voltage due to the next succeeding cycle and any variation in signal voltage due to movement of the L.V.D.T. during this period will, therefore, be detected by the change in voltage level present when the switch opens if compared with the level held during the

previous cycle. To prevent loss of charge on the capacitor during the time the switch is open the capacitor is followed by a non-inverting buffer amplifier with a high input impedance. A suitable type which is readily available is an insulated gate F.E.T. amplifier such as a CA3140E. The voltage level of the output from the buffer amplifier is, therefore, a true measure of the position of the L.V.D.T. Reference to Fig. 1 shows that this voltage is subject to variation whilst the switch is closed, ie. throughout the duration of gating Pulse 'A' especially when the L.V.D.T. is near the beginning or end of its stroke. This variation or ripple is removed by sampling the output from the 1st buffer by means of gating Pulse 'B' after gating Pulse 'A' has closed the gate. The 2nd sample & hold circuit is identical with the first and has a buffered output. The output of the 2nd buffer is, therefore, devoid of ripple at oscillator frequency and is used as the 'Position Output' signal from Channel 1. A similar 'Position Output' signal is obtained from Channel 2. The use of this additional signal is described later.

The 'Velocity Output' is obtained from the 'Position Output' in the following manner. The output level from the 1st buffer is sampled a second time in each cycle by gating Pulse 'D' which controls a 3rd sample and hold circuit, identical in details with the previous two circuits. At the end of a cycle the output levels from the 2nd and 3rd buffers will be identical. During the 2nd quadrant of the next cycle the output from the 2nd buffer will be updated to take into account any change in L.V.D.T. position during one oscillator cycle. At this instant in time the output level of the 3rd buffer is that of the previous cycle. During the 4th quadrant of the new cycle the output of the 3rd buffer is updated again to the new level of the 2nd buffer. The output of the 2nd buffer feeds the non-inverting input of a differential amplifier. The output of the 3rd buffer feeds the inverting input of the same amplifier. Thus the output from this amplifier is proportional to the difference in 'Position Level' between succeeding cycles during quadrant 2 to quadrant 4 and zero at other times. Gating Pulse 'C' which occurs during the 3rd quadrant is used to drive a fourth sample and hold circuit which samples the output from the differential amplifier during the period that the inputs are fed from the succeeding cycles. The output of the 4th buffer is, therefore, a true measure of the change in position which has occurred during one cycle, ie. the velocity of the motion. This then is the 'Velocity Output' and its polarity is dependant on the direction of motion making eminently suitable for feedback control purposes. The process is shown diagrammatically in Fig. 2. A similar 'Velocity Output' is obtained from Channel 2.

When Channel 1 and Channel 2 are fed from the same L.V.D.T. the two 'Velocity Output' voltages should be virtually identical. When two separate L.V.D.T.'s are used there may be a small permissible difference determined by the requirements of the mechanical device being controlled. The two 'Velocity Output' voltages are, therefore, compared by a further differential amplifier. The output of this amplifier feeds into two comparators with reference voltages set to give a band gap equivalent to the maximum permissible error. The output from each comparator is normally 'HIGH'. Errors greater than permissible in either 'Velocity Output' voltage will cause one comparator to change state. The resulting 'LOW' will produce the 'FAILURE' signal. This is the second part of the surveillance system and automatically checks the integrity of gating pulses C & D and their respective sample and hold circuits in each channel.

The two 'Velocity Output' signals can be fed out separately, with filter networks to eliminate high frequency noise where necessary, and used for control purposes. Alternatively, the two signals can be averaged by summing them together in a summing amplifier with the closed loop gain adjusted to give the desired range of output voltage. This single output, filtered where necessary, can be used for velocity feedback purposes in any suitable control system, eg. a servo system.

Reverting to the 'Position Output' signals from Channel 1 and Channel 2:—The two signals are compared in the same manner as the 'Velocity Output' signals with comparators set to a band gap equivalent to the maximum permissible error in position between the two channels. A 'LOW' from either comparator will produce the 'FAILURE' signal. This is the third part of the surveillance system and automatically checks the integrity of gating pulses A & B and their respective sample and hold circuits.

The differential amplifier used in the third part of the surveillance system, directly compares the 'Position Output' signals from the two channels. This, however, is a true measure of the error in position of the mechanical devices driving the two L.V.D.T.'s. The error signal can, therefore, be suitably processed to provide a correction for the two motions to bring them into synchronisation and reduce the error to an acceptable low value. For example, in a press where the platen is moved by two hydraulic actuators, the error signal could be used to drive a suitable interface such as an electrohydraulic valve to increase the fluid flow to one actuator and reduce it to the other to correct any difference in motion between the two actuators. Alternatively, the error signal could be used to spill off some fluid from the actuator which is moving too fast.

The two 'Position Output' signals, filtered where necessary, can be fed out separately and used for control purposes; alternatively, they can be summed and meaned to give a single signal. A D.C. voltage offset can be introduced at this stage to make the zero signal output coincide with the mechanical zero reference point. The combined output signal, filtered where necessary, can be used as a feedback signal in a positional servo system or in some other way.

The 'Position Output' signal could be compared with a 'Reference Position' signal generated by a potentiometer or digitally by thumbwheel switches, a computer or a microprocessor. When 'Position' and 'Reference' become coincident a signal is obtained for control purposes:— For example to stop the slide of a machine tool or the platen of a press at a precise and repeatable position, which can be selected at will by changing the 'Reference' signal. Either of the following methods could be emp-

loyed:—

The digital 'Reference' signal could be converted to an analogue voltage and compared directly with the analogue 'Position Output' signal. Alternatively, the analogue 'Position Output' signal could be converted to a digital signal and compared with the digital 'Reference' signal by means of a suitable counter.

A block diagram of one version of this invention using two L.V.D.T.'s is given in Fig. 3.

There will be many applications for this invention where all the available output signals are not required. The invention, therefore, consists of any features of novelty described herewith, taken singly or in any combination.

CLAIMS

1. An electronic conditioning system for the sinusoidal signals from an inductive type of transducer which is self monitoring and which by means of a plurality of sample and hold circuits triggered from an oscillator with dual outputs in quadrature, which also provides the excitation for the said transducer produces a demodulated output which is devoid of excitation frequency ripple together with a second output which gives the rate of change of the first output.

2. An electronic conditioning system for an inductive type of position transducer which is self monitoring and which by means of a plurality of sample and hold circuits triggered from an oscillator with dual outputs in quadrature, which also provides the excitation for the said position transducer, produces a demodulated output signal of position of motion which is devoid of excitation frequency ripple together with a second output which is the velocity of motion without the need to use an additional velocity transducer.

3. A system which as claimed in claim 1 or 2 produces a failure signal in the event of an electrical failure occurring in the transducer or the conditioning unit, by continuous monitoring of the oscillator signals, the transducer output signals and the sample and hold circuits.

4. A system which as claimed in claims 2 and 3 produces a failure signal in the event of an electrical failure occurring in position transducer or the conditioning unit, which can be used to stop the motion or otherwise ensure the safety of the equipment producing the motion.

5. A system which as claimed in claims 2, 3 and 4 but employing two position transducers driven from separate motions produces a further output signal which is proportional to the difference in position of the two motions which can then be used to synchronise the two motions.

6. An electronic system which is substantially as described with reference to the block diagram Fig. 3.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1981.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

2068124

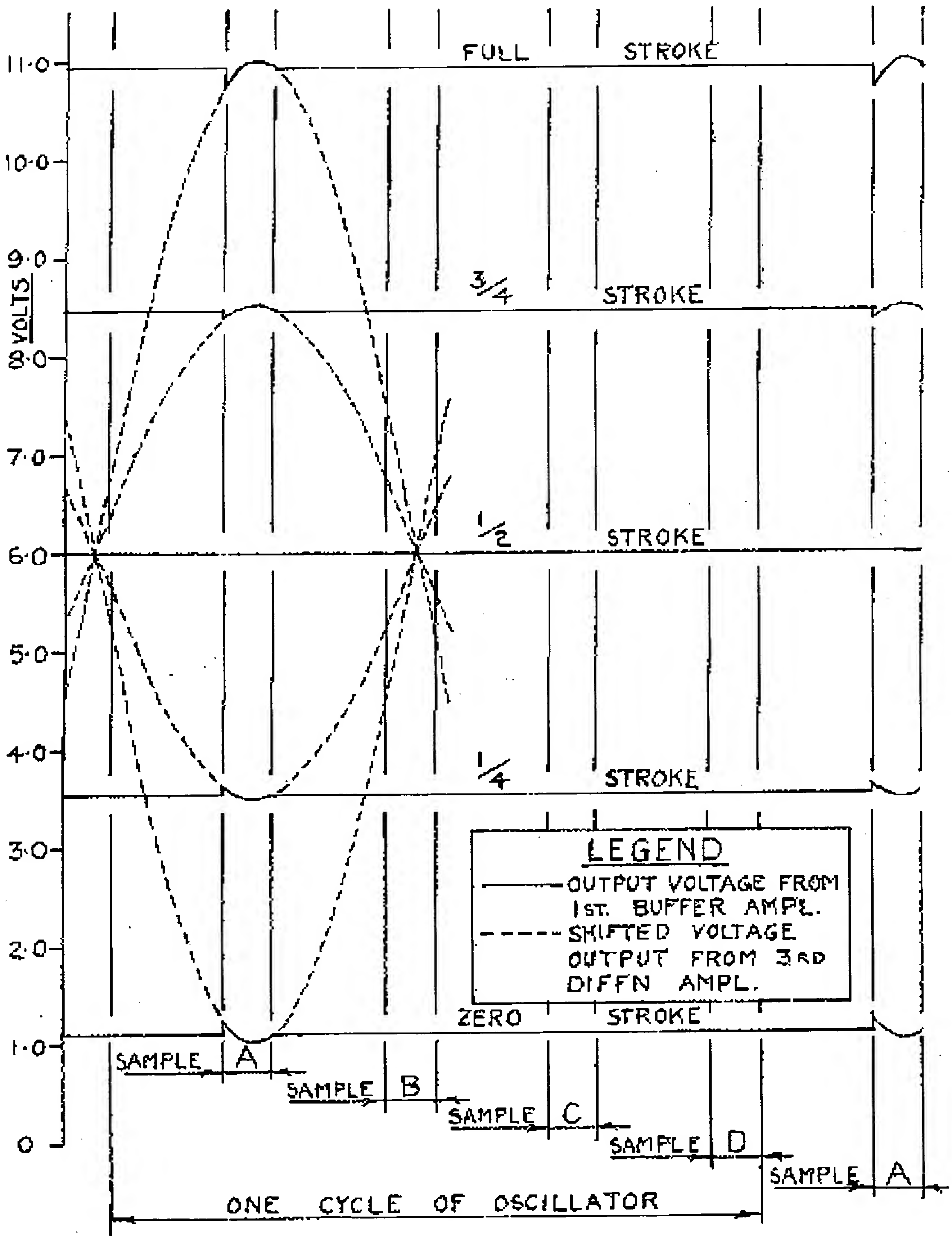


FIG.1.

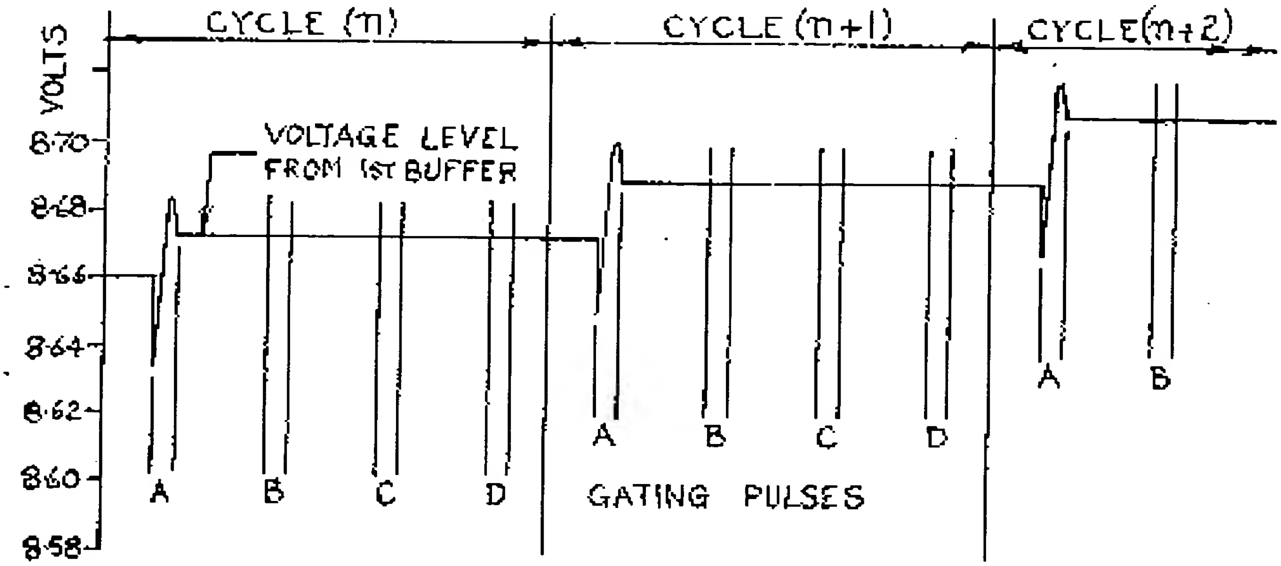
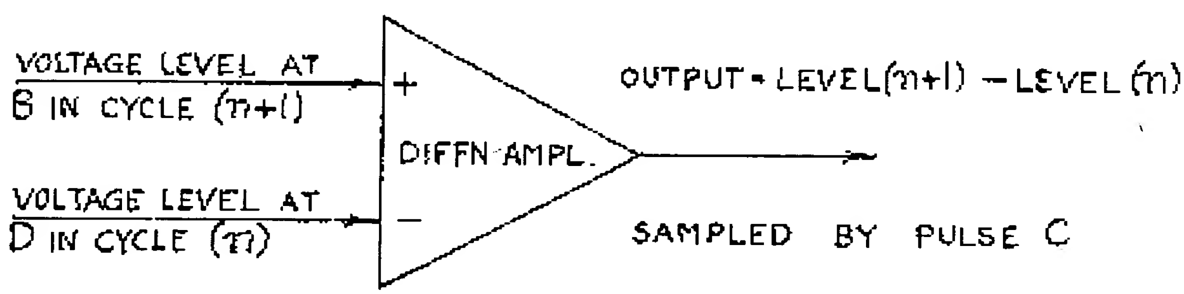
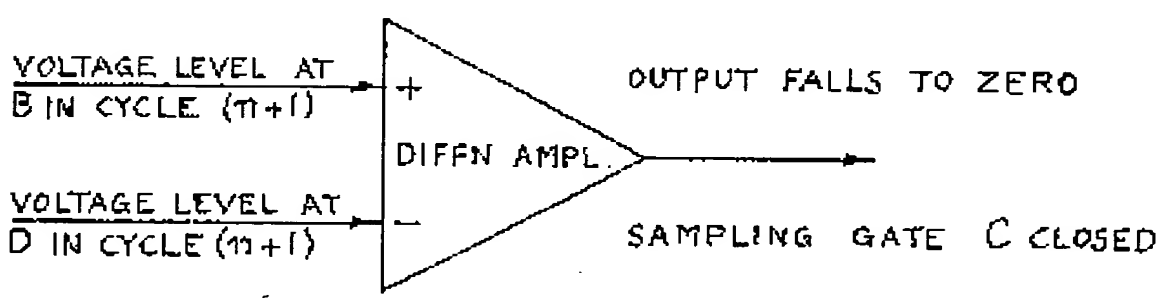


FIG 2a



CONDITION AT THE ARRIVAL OF GATING PULSE C IN CYCLE (n+1)

FIG 2b



CONDITION AT THE END OF GATING PULSE D IN CYCLE (n+1)

FIG 2c

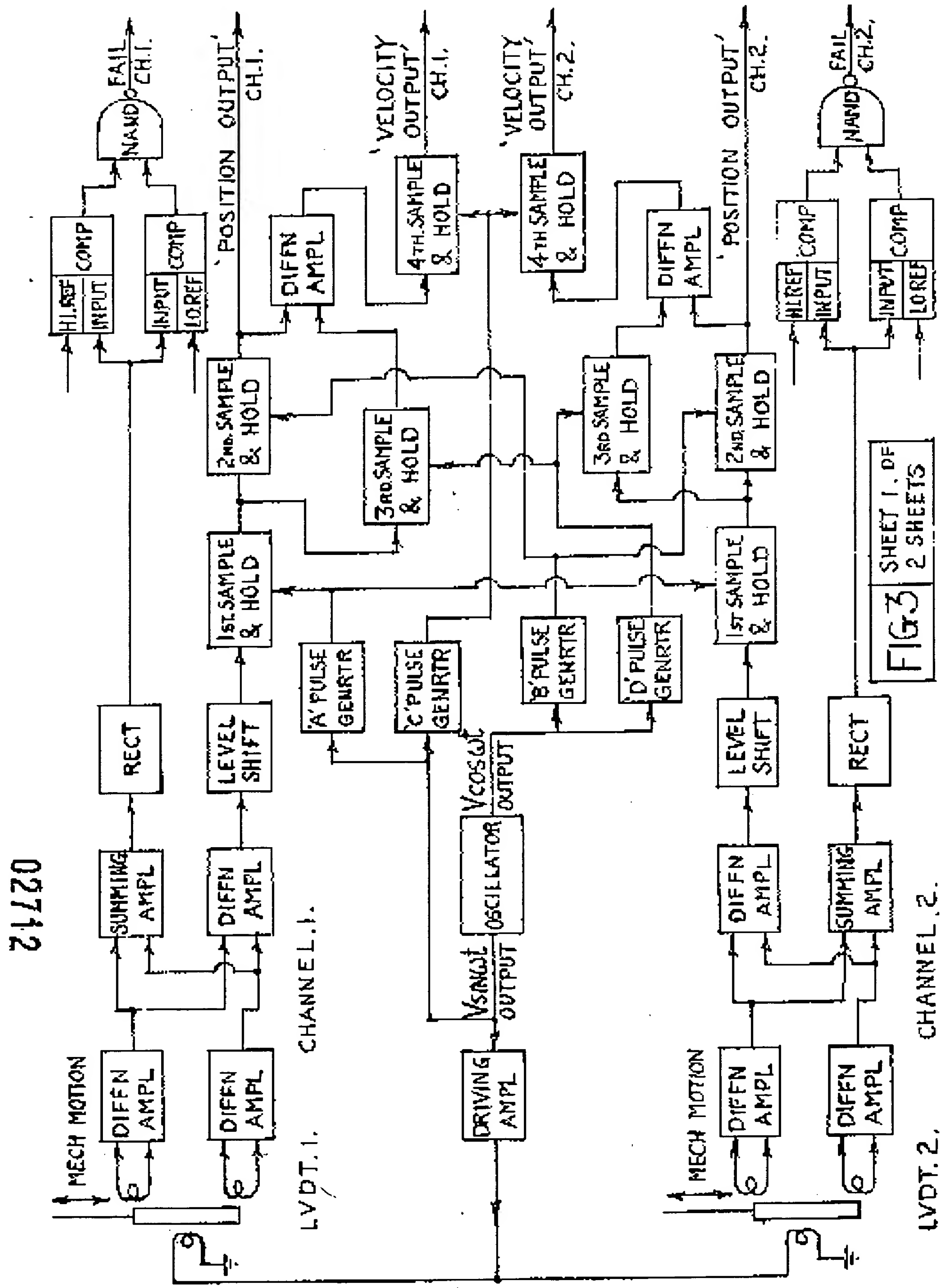

FAIL CH.1.
NAND
H.I.REF
INPUT
COMP
INPUT
LO.REF
COMP
'POSITION OUTPUT' CH.1.
'VELOCITY OUTPUT' CH.1.
'VELOCITY OUTPUT' CH.2.
'POSITION OUTPUT' CH.2.
FAIL CH.2.
NAND
HI.REF
INPUT
COMP
INPUT
LO.REF
COMP
DIFFN AMPL
4TH. SAMPLE & HOLD
4TH SAMPLE & HOLD
DIFFN AMPL
2ND. SAMPLE & HOLD
3RD. SAMPLE & HOLD
3RD SAMPLE & HOLD
2ND. SAMPLE & HOLD
1ST. SAMPLE & HOLD
1ST SAMPLE & HOLD
'A' PULSE GENRTR
'C' PULSE GENRTR
'B' PULSE GENRTR
'D' PULSE GENRTR
RECT
LEVEL SHIFT
LEVEL SHIFT
RECT
SUMMING AMPL
DIFFN AMPL
VCOSωt OUTPUT
OSCILLATOR
VSINωt OUTPUT
DIFFN AMPL
SUMMING AMPL
CHANNEL.1.
CHANNEL.2.
MECH MOTION
DIFFN AMPL
DIFFN AMPL
DRIVING AMPL
MECH MOTION
DIFFN AMPL
DIFFN AMPL
LVDT.1.
LVDT.2.
SHEET 1. OF 2 SHEETS

FIG 3

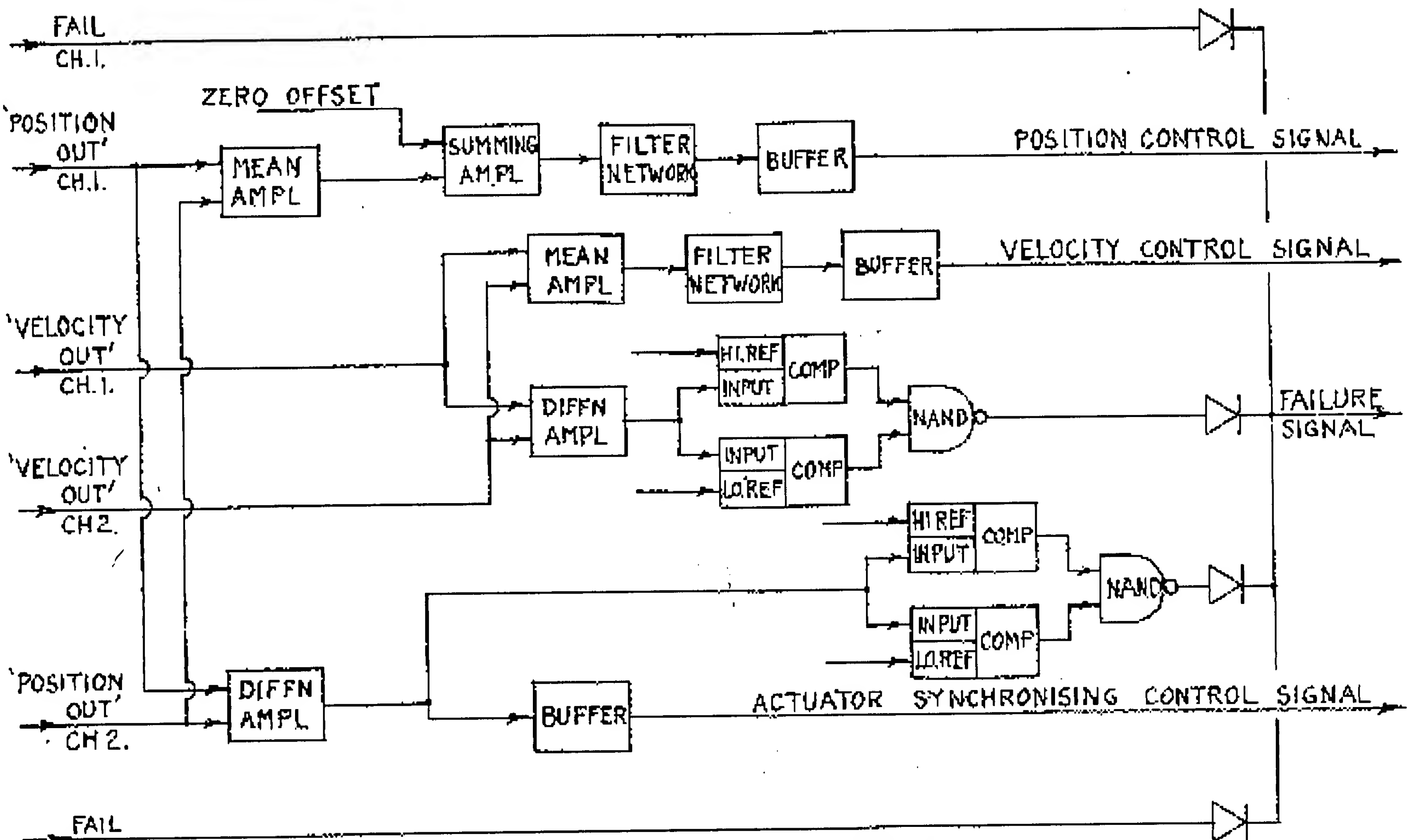


FIG3 SHEET 2 OF 2 SHEETS